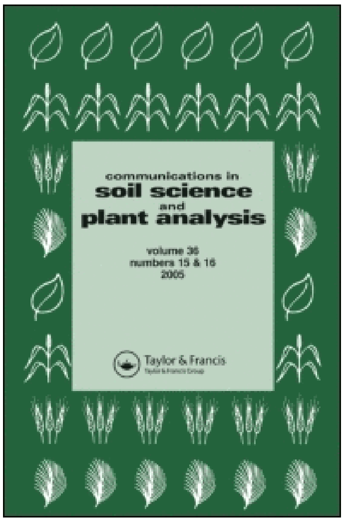
This article was downloaded by: *[USDA Natl Agricultul Lib]*
On: *3 June 2010*
Access details: *Access Details: [subscription number 917343524]*
Publisher *Taylor & Francis*
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Communications in Soil Science and Plant Analysis
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597241

IMPROVING NUTRIENT USE EFFICIENCY OF ANNUAL CROPS IN BRAZILIAN ACID SOILS FOR SUSTAINABLE CROP PRODUCTION

N. K. Fageria[a]; V. C. Baligar[b]
[a] National Rice and Bean research Center of Embrapa, GO, Brazil [b] Appalachian Farming System Research Center, Beaver, WV, U.S.A.

Online publication date: 30 April 2001

To cite this Article Fageria, N. K. and Baligar, V. C.(2001) 'IMPROVING NUTRIENT USE EFFICIENCY OF ANNUAL CROPS IN BRAZILIAN ACID SOILS FOR SUSTAINABLE CROP PRODUCTION', Communications in Soil Science and Plant Analysis, 32: 7, 1303 — 1319

To link to this Article: DOI: 10.1081/CSS-100104114

URL: http://dx.doi.org/10.1081/CSS-100104114

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.informaworld.com/terms-and-conditions-of-access.pdf

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

COMMUN. SOIL SCI. PLANT ANAL., 32(7&8), 1303–1319 (2001)

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

IMPROVING NUTRIENT USE EFFICIENCY OF ANNUAL CROPS IN BRAZILIAN ACID SOILS FOR SUSTAINABLE CROP PRODUCTION

N. K. Fageria[1] and V. C. Baligar[2]

[1] National Rice and Bean research Center of Embrapa,
Caixa Postal 179, Santo Antõnio de Goiás, GO 75375–000, Brazil
E-mail: fageria@cnpaf.embrapa.br
[2] USDA-ARS, Appalachian Farming System Research Center,
Beaver, WV 25813, USA
E-mail: vbaligar@asrr.arsusda.gov

ABSTRACT

In tropical acid soils, acidity is an important constraint for availability and uptake of nutrients by annual crops, and this leads to lower crop yields. Factors that contribute to low nutrient uptake efficiencies in these soils are low natural levels of most essential plant nutrients and unfavorable soil and plant environments. High P fixation capacity, Al, Mn and H toxicity, low activities of beneficial microorganisms, soil compaction, infestation of weeds, diseases and insects, drought and intensive monoculture are some of the major factors that contribute to the unfavorable soil and plant environments. Improving nutrient use efficiency in these soils demand adoption of special management practices. These practices include timely application of adequate levels of lime, gypsum and

Copyright © 2001 by Marcel Dekker, Inc. www.dekker.com

ORDER REPRINTS

fertilizers to meet crop demand, use of proper crop rotation, improvement of organic matter content, control of soil erosion and use of acid tolerant crop species and cultivars within species.

INTRODUCTION

Tropical agriculture is faced with a serious challenge of feeding about 70% of the world's inhabitants, and generating cash income to meet other basic necessities of life. A significant portion of population in tropical regions suffer from malnutrition. In addition, intensification and extension of agriculture into the marginal lands have created severe ecological problems (e.g. deforastation, soil degradation, environmental pollution and increased greenhouse gas emissions).

Tropical soils may be defined as all those soils that occur in the geographic tropics that is, in that region of the earth lying between the tropic of Cancer and the tropic of Capricorn, also known as the Torrid Zone (Eswaran et al., 1992). Diverse types of soils occur in the tropical regions. Acid and low fertility Oxisols and Ultisols cover about 43% of the tropics (Sanchez and Logan, 1992). Most of the central part of Brazil is tropical savanna, known as the Cerrado, covers about 205 million ha or 23% of the country. Most of the soils in this region are Oxisols (46%), Ultisols (15%), and Entisols (15%), with low natural soil fertility, high aluminum saturation and high P fixation capacity (Fageria and Stone, 1999). There are about 30 million ha of lowlands in Brazil, known locally as Varzea. These areas are distributed throughout the country and generally are under favorable climatic conditions for crop production. They represent a large portion of the acid lowlands of the world which can be brought under cultivation. At present, about 1.5 million ha of these Brazilian lowlands are under cultivation. Due to adequate water availability and the favorable climatic conditions, it is possible to produce three crops annually on these lands with proper technology. If this can be achieved, the quantity of food produced on these Brazilian lowland soils can contribute significantly to the total food production of the world. Generally, Varzea soils have good initial soil fertility but after two to three years of cultivation, the fertility of these soils is known to decline (Fageria and Baligar, 1996). Farming systems need to be developed based on improved soil management technology to bring these areas under sustainable, intensive crop production. The addition of sufficient amounts of nutrients is one of the key factors in improving crop yields and maintaining sustainable agricultural production on these lowlands. The objective of this paper is to suggest appropriate management strategies for improving nutrient efficiency of these Brazilian acid soils for sustainable crop production.

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Copyright © Marcel Dekker, Inc. All rights reserved.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

ORDER REPRINTS

MANAGEMENT STRATEGIES FOR IMPROVING NUTRIENT UPTAKE EFFICIENCY

Highly weathered Brazilian soils are acidic and have low natural levels of plant nutrients. The nutrient levels of these soils can be improved and depleted soils can be restored for sustainable crop production through management practices such as liming, application of adequate levels of fertilizers, control of soil erosion, increasing soil organic matter content, adoption of appropriate crop rotation and use of nutrient-efficient species and/or cultivars.

Liming

In tropical South America, 85% of the soils are acidic, and approximately 850 million ha of this area are under-utilized. The low yield of crops grown on acid soils is due to a combination of Al, Mn and H toxicity and deficiencies of N, P, K, Ca, Mg, Zn, Cu, and B. Most Brazilian soils are acidic and liming is the most common and effective practice for reducing soil acidity related problems. Lime significantly increased grain yields of annual crops such as common bean (*Phaseolus vulgaris L.*), corn (*Zea mays L.*), and soybean (*Glycine max L.* Merrill) grown on a Brazilian Oxisol (Table 1). Liming increases pH, Ca, Mg and base saturation and consequently improve crop yield (Fageria and Santana, 1998) As soil pH increases, the availability of P and Mo increases, whereas Mn, Cu, Fe and Zn availability decreases. The quantity of lime applied depends upon type of soil, quality of liming material, crop species/cultivar, and cost.

Table 2 shows optimum pH and base saturation levels for upland rice (*Oryza sativa L.*), common bean, corn and soybean on a Brazilian Oxisol. The optimum pH was 5.6 for upland rice, 6.2 for common bean, 6.4 for corn and 6.8 for soybean. Similarly, optimum base saturation level was 40% for upland rice, 53% for common bean, 59% for corn and 64% for soybean. Therefore, upland rice was most tolerant to soil acidity and soybean was most sensitive. For Brazilian Oxisols, the optimum pH for most annual crops is considered to be in the range of 5.5 – 6.7 (Fageria and Stone, 1999). Similarly, the optimum base saturation values varied from 50–60% for most annual crops in Brazilian Oxisols (Raij and Quaggio, 1997).

Use of Optimum Rate of Essential Nutrients

There are three main criteria that can be used in defining adequate rate of essential nutrients. The first criterion is soil test calibration data relating nutrient

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Copyright © Marcel Dekker, Inc. All rights reserved.

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

ORDER REPRINTS

Table 1. Response of Upland Rice, Common Bean, Corn, and Soybean to Liming Grown on an Oxisol[1]

Lime Rate ($t\ ha^{-1}$)	Upland Rice	Common Bean	Corn	Soybean
0	4559	1394	6490	1054
4	4568	1589	7659	1214
8	4434	1912	8501	1441
12	4590	1760	7862	1395
16	4659	1481	7653	1401
20	4413	1466	8221	1498
F test	NS	**	**	*
C V (%)	8	13	7	16
Regression				
β_0	4531.31	1402.89	6730.55	1067.22
β_1	8.16	76.37	218.14	46.29
β_2	−0.51	−3.86	−8.05	−1.33
R^2	0.02^{NS}	0.61**	0.48**	0.44*

*, **, ^{NS} Significant at the 5 and 1% probability level and nonsignificant, respectively.
[1] A field experiment was conducted during 4 consecutive years in a upland rice-common bean-corn-soybean rotation and values are average of two years for each crop.

concentration and crop response. This approach is applicable to immobile nutrients in the soil-plant system. In case of mobile nutrients such as N, soil test calibration data have little use and crop response curves relating N rates and yield should be more useful in making N fertilizer recommendations. Soil and plant analysis are other two approaches which can be used in determining optimum rates of essential nutrients in crop production and maintaining the sustainability of agriculture system.

Nitrogen Deficiency

Nitrogen deficiency is a major limiting nutrient for plant growth in acid soils of tropical and temperate regions. In tropical America, N deficiency is a major soil constraint over 93% of the region occupied by Oxisols and Ultisols (Sanchez and Salinas, 1981). The main reasons for widespread N deficiency in these tropical soils are: a) lower rate of N applied compared to rates of N removed in the harvested portion of the crops, b) loss of N by leaching, denitrification, and volatilization, and c) decline in soil organic matter content with successive cultivation.

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Copyright © Marcel Dekker, Inc. All rights reserved.

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

ORDER REPRINTS

Table 2. Optimum pH and Base Saturation Levels for Upland Rice, Common Bean, Corn, and Soybean Grown on Brazilian Oxisol[1]

Crop	Regression Equation	R^2	Optimum Level
	pH in water		
Upland rice	$Y = -1690.26 + 2075.76X - 172.04X^2$	0.14^{NS}	5.6
Common bean	$Y = -35830.82 + 12102.24X - 974.26X^2$	0.64**	6.2
Corn	$Y = -72985.20 + 25033.45X - 1930.93X^2$	0.71**	6.4
Soybean	$Y = -11262.64 + 3721.40X - 271.73X^2$	0.93**	6.8
	Base saturation (%)		
Upland rice	$Y = 3511.62 + 43.67X - 0.44X^2$	0.05^{NS}	40
Common bean	$Y = -3269.13 + 189.04X - 1.79X^2$	0.45*	53
Corn	$Y = -5191.99 + 450.93X - 3.79X^2$	0.49**	59
Soybean	$Y = -1672.08 + 100.42X - 0.80X^2$	0.47**	63

*, **, ^{NS} Significant at the 5 and 1% probability level and nonsignificant, respectively.

[1] A field experiment was conducted during 4 consecutive years in a upland rice-common bean-corn-soybean rotation and values are average of two years for each crop.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

Copyright © Marcel Dekker, Inc. All rights reserved.

ORDER REPRINTS

Table 3. Response of Rice and Common Bean Grown in Rotation to Fertilization in Cerrado and Varzea Soils

Fertlity Level	Rice Grain Yield (kg ha^{-1})[1]	Common Bean Grain Yield (kg ha^{-1})[1]
	Cerrado soil[2]	
Low	1684b	1230c
Medium	2117a	1818b
High	2104a	2162a
Medium + green manure	2403a	1537a
F test	*	**
	Varzea soil[3]	
Low	4327b	294b
Medium	5523a	663a
High	5465a	851a
Medium + green manure	6332a	823a
F test	**	**

[1] Values are averages of three crops grown in rice-bean rotation.
*, ** significant at the 5 and 1% probability levels, respectively. Within same column, means followed by the same letter do not differ significantly at 5% probability levels by Tukey's test.
[2] Cerrado soil fertility levels for rice were low (without addition of fertilizers); medium (50 kg N ha^{-1}, 26 kg P ha^{-1}, 33 kg K ha^{-1}, 30 kg ha^{-1} fritted glass material as a source of micronutrients); high (all the nutrients applied were the double the medium level). *Cajanus cajan L.* was used as a green manure at the rate of 25.6 t ha^{-1} green matter. For common bean the fertility levels were low (without addition of fertilizers); medium (35 kg N ha^{-1}, 44 kg P ha^{-1}, 42 kg K ha^{-1}, 30 kg ha^{-1} fritted glass material as a source of micronutrients) and high (all the nutrients applied were double the medium level).
[3] Varzea soil fertility levels for rice were low (without addition of fertilizers); medium (100 kg N ha^{-1}, 44 kg P ha^{-1}, 50 kg K ha^{-1}, 40 kg ha^{-1} fritted glass material as a source of micronutrients); and high (all the nutrients applied were double the medium level). *Cajanus cajan L.* was used as a green manure at the rate of 28 t ha^{-1} green matter. For common bean the fertility levels were low (without addition of fertilizers); medium (35 kg N ha^{-1}, 52 kg P ha^{-1}, 50 kg K ha^{-1}, 40 kg fritted glass material as a source of micronutrients) and high (all the nutrients applied were double the medium level).
Source: Fageria and Souza, 1995; Fageria and Baligar, 1996.

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Copyright © Marcel Dekker, Inc. All rights reserved.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

ORDER REPRINTS

Table 4. Response of Lowland Rice to Nitrogen Fertilization on a Lowland Acid Soil of Central Brazil

N Rates ($kg\ ha^{-1}$)	1st Crop	2nd Crop	3rd Crop	Average
	$kg\ ha^{-1}$			
0	3579	3754	3702	3678
30	3900	4971	3972	4281
60	5383	6159	5265	5602
90	5946	5883	5109	5646
120	6231	7044	5757	6344
150	6439	6945	5703	6362
180	7101	6488	5527	6372
210	6862	6975	5330	6389
F test (N)	**	**	**	**
F test (crop)				**
F test (N × C)				*
CV(%)	8	10	12	10
Regression				
β_0	3400.87	3900.88	3560.27	3620.50
β_1	33.87	37.50	28.55	33.31
β_2	−0.08	−0.11	−0,10	−0.10
R^2	0.96**	0.92**	0.92**	0.99**

*,** Significant at 5 and 1% probability levels, respectively.
Source: Fageria, 1998.

Rice and common bean responded to fertilizer application on Cerrado and Varzea soils of Brazil (Table 3). Rice grown on Varzea soil responded significantly up to 210 kg N ha^{-1}, however, the 90% of the maximum yield was obtained at about 100 kg N ha^{-1} (Table 4). In Brazil an average of 60 kg N ha^{-1} is generally used for lowland rice. By increasing N application to 100 kg ha^{-1} rice yield could be increased substantially.

Phosphorus Deficiency

Phosphorus deficiency also limits crop yield on the Cerrado as well as Varzea soils of Brazil (Fageria and Baligar 1997a; Fageria et al., 1997) The two main reasons for P deficiency in these acid soils are low natural levels of soil P and capacity to fix high levels of added P. Fageria and Barbosa Filho (1987) have reported that in Oxisol of central Brazil the amount of P fixed (added P not recov-

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Copyright © Marcel Dekker, Inc. All rights reserved.

ORDER REPRINTS

Table 5. Mehlich-1 Soil Test P Availability Indices and P Fertilizer Recommendations for Lowland Rice Grown on an Acid Inceptisol of Central Brazil

Soil P Test (mg kg^{-1})	P Test Interpretation	Broadcast P Application (kg ha^{-1})	Band P Application (kg ha^{-1})
0–3.0	Very low	306	52
3.1–6.4	Low	219	44
6.4–12.0	Medium	153	35
>12	High	0	26

Source: Fageria, 1999.

ered by Mehlich 1 extracting solution) increased from 45 to 268 kg P ha^{-1} as the P application rate increased from 50 to 400 kg P ha^{-1}. Therefore, to maintain adequate P supply in these high P fixing soils to support optimum crop yields there is need for application of large amounts of P fertilizer. The soil P test availability indices and P fertilizer recommendations for lowland rice grown on a Brazilian Inceptisol are presented in Table 5.

Potassium Deficiency

The need for K application of annual crops is not as widespread and significant as that for N and P on the Cerrdao and Varzea soils of Brazil. However, K is absorbed in greater quantities by annual crops, especially the high yielding cultivars. A single upland rice crop grown on an Oxisol of Cerrado soil producing 4795 kg ha^{-1} of grains in about 130 days used 159 kg N ha^{-1}, 13 kg P ha^{-1}, and 189 kg K ha^{-1} (Fageria, 1998). Where intensive agriculture is practiced, failure to replace K that is removed in the harvest can result in K deficiency. Response of upland and lowland rice to added K in Cerrado and Varzea soils of Brazil has been reported by Fageria et al. (1989, 1990b). In these studies K significantly increased upland and lowland rice grain yields but the response varied from cultivar to cultivar and year to year. Applied K were rapidly removed from the soil by crops and leaching to lower depths and yearly application of K can be expected to result in a significant increase in rice grain yield.

Three management practices can be used to improve K fertilizer recover and use efficiency by plants growing on acid soils. First, K fertilizers should be applied at an economically feasible rate, bearing in mind the crop requirement and the long term need to replace K that is lost through crop removal and leaching. Second, the incorporation of crop residues in the soil after harvest enables a substantial amount of the K to be recycled. Approximately 85 to 92% of the total K

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Copyright © Marcel Dekker, Inc. All rights reserved.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

ORDER REPRINTS

Table 6. Dry Matter and Grain Yield and Nutrients Accumulation by Upland Rice, Common Bean, Corn, and Soybean Grown in Rotation on an Oxisol of Central Brazil

		Upland Rice		Common Bean		Corn		Soybean	
Nutrient and Yield		Shoot	Grain	Shoot	Grain	Shoot	Grain	Shoot	Grain
Yield	(kg ha^{-1})	6642	4794	1773	1674	13670	8148	2901	1323
N	(kg ha^{-1})	80	80	19	68	82	128	57	90
P	(kg ha^{-1})	4	9	1	5	5	17	8	9
K	(kg ha^{-1})	174	15	37	31	108	19	44	24
Ca	(kg ha^{-1})	27	2	21	5	34	8	48	5
Mg	(kg ha^{-1})	19	5	8	4	18	8	16	3
Zn	(g ha^{-1})	159	136	45	73	183	196	75	87
Cu	(g ha^{-1})	35	51	12	21	60	8	95	31
Mn	(g ha^{-1})	1308	395	91	17	366	81	269	27
Fe	(g ha^{-1})	523	148	398	129	974	163	1277	172
B	(g ha^{-1})	40	20	26	14	137	49	38	21

Source: Fageria, 1998.

content remains in the vegetative shoot of cereals such as rice and corn and 54 to 65% of plant K remain in the shoot of legumes such as common bean and soybean (Table 6). The third practice involves the use of K-efficient cultivars that have an increased K uptake efficiency.

Calcium, Magnesium, and Sulfur Deficiency

Deficiencies of Ca, Mg and S are also important limitations to plant growth in acid soils. Crops removed from about 26 to 53 kg Ca ha^{-1} and 12 to 26 kg Mg ha^{-1}, from an Oxisol of central Brazil depending on the yield and the particular crop (Table 6). Crop requirements of Ca and Mg in soils that are deficient in these elements can be met with the application of dolomitic lime (Fageria and Stone, 1999). Adequate levels of Ca, Mg and saturation of these elements were determined for upland rice, common bean, corn, and soybean grown in sequence on a Brazilian Oxisol (Table 7).

Gypsum ($CaSO_4.2H_2O$) can also be used to improve Ca content of acid soils. In Cerrado soils of Brazil, gypsum applications for annual crop production are made on the basis of basis of clay content using the formula (Sousa and Lobato, 1996): Gypsum requirement (kg ha^{-1}) $= 50 \times$ clay content (%). In addition to Ca, gypsum also supplies S. The Ca^{2+} and SO_4^{2-} in gypsum form an ion pair which is more mobile and leaches to subsoil horizons where native Ca levels may be too low to support root growth. The ionic strength of the soil solution is increased by gypsum, and lowers the activity of Al^3. Further, Sulfate forms ion pairs

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Copyright © Marcel Dekker, Inc. All rights reserved.

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

ORDER REPRINTS

Table 7. Relationship Between Exchangeable Ca and Mg (X) Parameters and Grain Yield (Y) of Upland Rice, Common Bean, Corn, and Soybean Grown on an Oxisol of Central Brazil

Ca and Mg Parameter	Regression Equation	R^2	Adequate Level[1]
	Upland rice		
Ca ($mmol_c\ dm^{-3}$)	$Y = 4029.37 + 43.07X - 0.84X^2$	0.20^{ns}	18
Mg ($mmol_c\ dm^{-3}$)	$Y = -2800.39 + 12.47X - 0.52X^2$	0.81**	12
Ca (saturation (%))	$Y = 4071.01 + 31.43X - 0.48X^2$	0.22^{NS}	21
Mg (saturation (%))	$Y = -595.03 + 696.33X - 23.29X^2$	0.70**	15
	Common bean		
Ca ($mmol_c\ dm^{-3}$)	$Y = -1648.45 + 237.43X - 4.13X^2$	0.80**	29
Mg ($mmol_c\ dm^{-3}$)	$Y = -16209.33 + 2844.50X + 112.82X^2$	0.43*	13
Ca (saturation (%))	$Y = -1266.18 + 164.77X - 2.24X^2$	0.62**	37
Mg (saturation (%))	$Y = -978.32 + 1429.21X - 44.42X^2$	0.40*	16
	Corn		
Ca ($mmol_c\ dm^{-3}$)	$Y = -138.87 + 497.33X - 7.46X^2$	0.73**	33
Mg ($mmol_c\ dm^{-3}$)	$Y = -30640.46 + 5708.76X - 209.40X^2$	0.81**	14
Ca (saturation (%))	$Y = 760.8652 + 342.98X - 3.98X^2$	0.72**	43
Mg (saturation (%))	$Y = -17743.14 + 2929.85X - 82.48X^2$	0.81**	18
	Soybean		
Ca ($mmol_c\ dm^{-3}$)	$Y = -130.95 + 81.71X - 1.03X^2$	0.96**	40
Mg ($mmol_c\ dm^{-3}$)	$Y = -7735.49 + 1297.30X - 46.61X^2$	0.99**	14
Ca (saturation (%))	$Y = -1.20 + 57.94X - 0.56X^2$	0.96**	52
Mg (saturation (%))	$Y = -4781.56 + 693.09X - 19.15X^2$	0.99**	18

*, ** Significant at the 0.05 and 0.01 probability level, respectively.
[1] Adequate level was calculated by regression equation, where R^2 was significant and when R^2 was nonsignificant, original soil value was considered adequate.

such as $AlSO_4^{++}$ which is less toxic to plants than Al^{3+}. In some Cerrado soils of Brazil when SO_4^{2-}-S is below 10 mg kg^{-1}, crop responses to applied S have been reported (Malavolta et al., 1987). These authors have also reported that crops are likely to benefit from the addition of S containing fertilizers at the rates of 20 kg S ha^{-1}.

Micronutrient Deficiency

Brazilian soils are generally low in available Zn and deficiency of this nutrient has been reported in upland as well as lowland rice, corn and soybean

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Copyright © Marcel Dekker, Inc. All rights reserved.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

ORDER REPRINTS

(Fageria et al., 1997). Most of the Brazilian soils are acidic and liming is an essential practice to improve soil pH and decrease toxicity of toxic elements such as Al^{3+} and Mn. With increasing soil pH due to liming the ionic forms of the micronutrient cations forms insoluble hydroxides or oxides and induce deficiency of the elements to crops. For example iron deficiency results in upland rice when soil pH in Brazilian Oxisols is raised to 6.0 by liming (Fageria, 1998). The best management strategy is to avoid over liming these soils. Application of about 2 to 5 kg Zn ha^{-1} through zinc sulfate to these soils can correct the zinc deficiency for most of the annual crops. Foliar spray of micronutrients is also an important strategy to correct deficiency in annual crops. Table 8 shows adequate and toxic levels of Zn, Cu, Mn, and B in soil and plant tissue of upland rice, common bean, corn, soybean, and wheat grown on an Oxisol of central Brazil under greenhouse conditions. These values can be used as reference in soil and plant analysis and correcting micronutrient deficiencies in crops.

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Control of Soil Erosion and Consideration of Soil Organic Matter

Water erosion causes top soil loss and decreased soil productivity of arable lands under Brazilian conditions. Top soil depth has been often used to evaluate soil quality and productivity. Loss of top soil usually reduces the amount of plant-available water and nutrients and leads to reduced productivity. Soil erosion can be reduced to tolerable levels by adopting erosion control structures (terraces, strip) and management practices such as contour planting, cover cropping, and conservation tillage. These practices can reduce the rate of soil erosion and contribute to higher nutrient use efficiencies in Brazilian soils.

Soil organic matter (SOM) is linked to desirable soil physical, chemical, and biological properties and is closely associated with soil productivity. As a chemical reservoir, there is universal acknowledgement that SOM is the major indigenous source of soil-available N, P, S and other essential nutrients. Some cultural practices such as incorporation of crop residues, use of organic manures, use of proper crop rotation and conservation tillage systems are important strategies for maintaining adequate levels of SOM and reducing potential soil erosion.

Use of Crop Rotation

Crop rotation has many advantages such compared to monoculture such as improving SOM content, reducing incidence of insects, weeds and diseases, and minimizing the N fertilizer requirement for optimal grain yield. For crops following legumes, the reduced N fertilizer input is often attributed to N_2 fixed by the preceding legume crop that is released through decomposition of roots and

Copyright © Marcel Dekker, Inc. All rights reserved.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Table 8. Adequate and Toxic Levels of Micronutrients for Five Annual Crops Grown on an Oxisol of Central Brazil

Crop	Adequate Level in Soil (mg kg^{-1})[1]		Toxic Level in Soil (mg kg^{-1})[1]		Adequate Level in Plant (mg kg^{-1})[1]	Toxic Level in Plant (mg kg^{-1})[1]
	Mehlich-1	DTPA-TEA	Mehlich-1	DTPA-TEA		
			Zinc[2]			
Upland rice	5	4	61	35	67	673
Common bean	0.7	0.3	25	25	18	133
Corn	2	1	94	60	27	427
Soybean	0.8	0.3	53	33	20	187
Wheat	0.5	0.3	27	34	19	100
			Copper[3]			
Upland rice	2	1	48	28	15	26
Common bean	1.5	0.5	35	18	6	10
Corn	2.5	1.5	45	32	7	11
Soybean	1.0	0.5	10	6	7	10
Wheat	10	8.5	52	28	14	17
			Manganese[4]			
Upland rice	8	4	168	80	520	4560
Common bean	8	6	128	88	400	1640

ORDER REPRINTS

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

Copyright © Marcel Dekker, Inc. All rights reserved.

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Corn	8	4	400	336	60	2480
Soybean	8	4	92	56	67	720
Wheat	8	3	44	40	173	720
Boron (hot water extraction)[5]						
Upland rice	0.4		2.3		10	20
Common bean	0.9		2.8		24	135
Corn	1.3		5.7		20	68
Soybean	2.6		5.2		75	155
Wheat	0.4		4.3		20	144

[1] Adequate level was determined at the 90% maximum yield and toxic level was determined at the reduction of 10% yield after achieving maximum yield.
[2] Rice plants were harvested 6 weeks after sowing, common bean, soybean and wheat plants were harvested 5 weeks after sowing, and corn plants were harvested 4 weeks after sowing.
[3] Rice, soybean, and wheat plants were harvested 4 weeks after sowing and common bean and corn plants were harvested 3 weeks after sowing.
[4] Rice and soybean plants were harvested 4 weeks after sowing and common bean, corn and wheat plants were harvested 3 weeks after sowing.
[5] Rice and wheat plants were harvested at physiological maturity and common bean, corn and soybean plants were harvested 4 weeks after sowing.

ORDER REPRINTS

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016
Copyright © Marcel Dekker, Inc. All rights reserved.

ORDER REPRINTS

Table 9. Critical Al Saturation for Important Field Crops at 90–95% of Maximum Yield

Crop	Type of Soil	Critical Al Saturation (%)
Cassava	Oxisol/Ultisol	80
Upland rice	Oxisol/Ultisol	70
Cowpea	Oxisol/Ultisol	55
Cowpea	Oxisol	42
Peanut	Oxisol/Ultisol	65
Peanut	Xanthic Halpludox	54
Soybean	Oxisol	19
Soybean	Xanthic Halpludox	27
Soybean	Oxisol/Ultisol	15
Soybean	Not given	<20
Soybean	Ultisol	20–25
Soybean	Histosol	10
Soybean	Ultisol	20
Corn	Oxisol	19
Corn	Xanthic	27
Corn	Oxisol/Ultisol	29
Corn	Oxisol/Ultisol	25
Corn	Oxisol	28
Mungbean	Oxisol/Ultisol	15
Mungbean	Oxisol/Ultisol	5
Coffee	Oxisol/Ultisol	60
Sorghum	Oxisol/Utisol	20
Common bean	Oxisol/Ultisol	10
Common bean	Oxisol/Ultisol	8–10
Common bean	Oxisol/Ultisol	23
Cotton	Not given	<10

Source: compiled from various sources by Fageria et al., 1997.

residues. Furthermore, rotated crop sequences may potentially provide available soil N through increases in SOM, soil microbial biomass, and mineralizable N. Selection and applicability of cropping systems in rotation are guided by climatic and economic factors. Specific crop rotation sequences are chosen for adaptability to the climate and soils of the area, performance in relation to other crops in the cropping sequence, and economic return. Choice of crop is greatly affected by the availability of water, which is generally determined by local environmental conditions. In Brazilian Cerrado as well as Varzea soils, rice-common bean-corn-soybean is one of the appropriate crop rotations. Another crop rotation may be

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Copyright © Marcel Dekker, Inc. All rights reserved.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

ORDER REPRINTS

soybean-corn-rice-common bean. In these rotations, the first crop is planted during the rainy season (October to March) and second crop is planted during dry season with irrigation (May to September).

Plant Genetic Variability

Use of nutrient-efficient or tolerant crop species and/or cultivars can be a complimentary solution for crop production on low fertility or acidic soils. Differences in crop cultivars use of N, P, and K have been reported by Fageria et al. (1988; 1990a; 1997) and Fageria and Baligar (1997b) under Brazilian conditions. Similarly, Extensive review of plant, soil and climatic factors that influence the nutrient use efficiency in plant species and cultivars within the species can be found in Baligar and Fageria (1997). For example, data given in Table 9 shows differences in Al tolerance of different crop species expressed on the basis of Al-saturation. Cassava (*Manihot esculenta* Crantz), upland rice, cowpea (*Vigna unguiculata L.*) and peanut (*Arachis hypogaea* L.) are most tolerant to Al-toxicity and cotton (*Gossypium hirstum L.*), common bean, soybean and mungbean (*Phaseolus aureus* Roxb.) are most sensitive.

CONCLUSIONS

Increasing crop yields has become essential to keep pace with the increasing world population. By improving recovery and nutrient use efficiency of highly weathered acid soils of the tropics, food production can be significantly increased. In Brazil there are vast areas which can be brought under cultivation but most of the soils in these areas are acidic and contain low natural levels of most of the essential plant nutrients to support productive crop growth. To obtain higher stable crop yields on these soils, the following management practices are suggested to improve nutrient recovery and use efficiency: (1) use of adequate rates of liming and fertilizers, (2) maintaining an adequate supply of organic matter, by use of organic manures where possibilities exist, on small holdings, or use of green manure on bigger holdings, (3) use of proper crop rotation with emphasis on increasing the area under grain legumes and forage legumes in the rotation so as to derive benefit from nitrogen fixation, (4) adoption of improved cultural practices to improve nutrient use efficiency, (5) use of nutrient efficient or tolerant cultivars in combination with soil amendments, (6) use of acid soils that have very low natural fertility and sandy texture for permanent pasture rather than crop production, and (7) adapt Integrated nutrient management system to improve the overall nutrient use efficiency by annual crops (Fageria and Baligar, 1997c).

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Copyright © Marcel Dekker, Inc. All rights reserved.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

ORDER REPRINTS

REFERENCES

Baligar, V. C. and N. K. Fageria. 1997. Nutrient use efficiency in acid soils: Nutrient management and plant use efficiency. pp.75–93. In: A. C. Moniz et al. (eds.) Plant-Soil Interactions at low pH: Sustainable Agricultural and Forestry Production. Brazilian Soil Sci. Soc. Campinas, Brazil.

Eswaran, H., J. Kimble, T. Cook and F. H. Beinroth. 1992. Soil diversity in the tropics: Implications for agricultural development. pp. 1–16. In: R. Lal and P. A Sanchez (ed.), Myths and science of soils of the tropics. SSSA special publication number 29, Madison, Wisconsin.

Fageria, N.K. 1998. Annual report of the project: The study of liming and fertilization for rice and common bean in cerrado region. National Rice and Bean Research Center, Santo Antonio de Goias, Brazil.

Fageria, N. K. 1999. Liming and fertilization of rice. pp.329–353. In: N. R. Vieira, A. B. Santos and E. P. Santana (ed.) Rice crop in Brazil. Embrapa Arroz e Feijão, Santo Antonio de Goias, Brazil.

Fageria, N.K. and Baligar, V.C. 1996. Response of lowland rice and common bean grown in rotation to soil fertility levels on a Varzea soil. Fertilizer Res. 45: 13–20.

Fageria, N.K. and Baligar, V.C. 1997a. Response of common bean, upland rice, corn, wheat, and soybean to soil fertility of an Oxisol. J. Plant Nutr. 20: 1279–1289.

Fageria, N.K. and Baligar, V. C. 1997.b Phosphorus use efficiency by corn genotypes. J. Plant Nutr. 20: 1267–1277.

Fageria, N. K. and V. C. Baligar. 1997c. Integrated plant nutrient management for sustainable crop production-Aa overview. Intern. J. Trop. Agric. 15: 1–18.

Fageria, N. K. V.C Baligar, and D.G. Edwards, 1990a. Soil-plant nutrient relationships at low pH stress. p.475–507. In: V.C. Baligar and R.R. Duncan (ed.). Crops as enhancers of nutrient use. Academic Press, San Diego.

Fageria, N. K., V. C. Baligar and C. A. Jones. 1997. Growth and Mineral nutrition of field crops. 2nd edition, Marcel Dekker, New York.

Fageria, N.K.; V.C Baligar,.; R.J Wright,. and J.R.P Carvalho,. 1990b. Lowland rice response to potassium fertilization and its effect on N and P uptake. Fertilizer Res. 21: 157–162.

Fageria, N.K. and M.P Barbosa Filho,. 1987. Phosphorus fixation in Oxisol of central Brazil. Fert. Agric. 94: 33–37.

Fageria, N.K.; O.P Morais,.; V.C Baligar,. and R.J Wright,. 1988. Response of rice cultivars to phosphorus supply on an Oxisol. Fertilizer Res. 16: 195–206.

Fageria, N. K. and E. V. P. Santana. 1998. Fertility problems and management of highly depleted Brazilian soils for optimization of crop production. Paper presented at the First International Agronomy Congress: Agronomy, Envi-

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Copyright © Marcel Dekker, Inc. All rights reserved.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

ORDER REPRINTS

ronment and Food Security for 21st century, New Delhi, India, 23–27 November 1998.

Fageria, N.K. and N.P Souza. 1995. Response of rice and common bean crops in succession to fertilization in cerrado soil. Pesq. Agropec. Brasileira, 30: 359–368.

Fageria, N. K. and L. F. Stone. 1999. Acidity management of cerrado and varzea soils of Brazil. Embrapa Arroz e Feijão, Document No.92, Santo Antonio de Goias, Brazil.

Fageria, N.K.; R.J Wright,.; V.C Baligar,. and J.R.P Carvalho,. 1989. Upland rice response to potassium fertilization. Fertilizer Res. 21: 157–162.

Malavolta, E.P.; Vitti, G.C.; Rosolem, C.A.; Fageria, N.K. and Guimaraes, P.T.G. 1987. Sulphur responses of Brazilian crops. J. Plant Nutr. 10: 2153–2158.

Raij, B.V. and Quaggio, J.A. 1997. Methods used for diagnosis and correction of soil acidity in Brazil: an overview. pp.205–214. In: A.C. Moniz et al. (ed). Plant Soil Interaction at low pH. Barzilian Soil Science Society, Campinas, Brazil.

Sanchez, P. A and T. J. Logan. 1992. Myths and science about the chemistry and fertility of soils in the tropics. pp.35–46. In: R. Lal and P. A Sanchez (ed.), Myths and science of soils of the tropics. SSSA special publication number 29, Madison, Wisconsin.

Sanchez, P.A and Salinas, J.G. 1981. Low-input technology for managing Oxisols and Ultisols in tropical America. Adv. Agron. 34: 279–406.

Sousa, D.M.G and E Lobato. 1996. Soil amendment and fertilization for soybean growth in cerrado soils. EMBRAPA-CPAC. Technical Circular, 33, Planaltina, Brazil.

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Copyright © Marcel Dekker, Inc. All rights reserved.

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

Downloaded By: [USDA Natl Agricultul Lib] At: 19:57 3 June 2010

Request Permission or Order Reprints Instantly!

Interested in copying and sharing this article? In most cases, U.S. Copyright Law requires that you get permission from the article's rightsholder before using copyrighted content.

All information and materials found in this article, including but not limited to text, trademarks, patents, logos, graphics and images (the "Materials"), are the copyrighted works and other forms of intellectual property of Marcel Dekker, Inc., or its licensors. All rights not expressly granted are reserved.

Get permission to lawfully reproduce and distribute the Materials or order reprints quickly and painlessly. Simply click on the "Request Permission/Reprints Here" link below and follow the instructions. Visit the U.S. Copyright Office for information on Fair Use limitations of U.S. copyright law. Please refer to The Association of American Publishers' (AAP) website for guidelines on Fair Use in the Classroom.

The Materials are for your personal use only and cannot be reformatted, reposted, resold or distributed by electronic means or otherwise without permission from Marcel Dekker, Inc. Marcel Dekker, Inc. grants you the limited right to display the Materials only on your personal computer or personal wireless device, and to copy and download single copies of such Materials provided that any copyright, trademark or other notice appearing on such Materials is also retained by, displayed, copied or downloaded as part of the Materials and is not removed or obscured, and provided you do not edit, modify, alter or enhance the Materials. Please refer to our Website User Agreement for more details.

Order now!

Reprints of this article can also be ordered at

http://www.dekker.com/servlet/product/DOI/101081CSS100104114